

CONSERVATION STATUS OF THE LAST SURVIVING WILD POPULATION OF HANGUL OR KASHMIR DEER *CERVUS ELAPHUS HANGLU* IN KASHMIR, INDIAKHURSHEED AHMAD^{1,3}, S. SATHYAKUMAR^{2,4} AND QAMAR QURESHI^{2,5}

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The Kashmir Deer or Hangul *Cervus elaphus hanglu*, a critically endangered deer, is one of the four easternmost subspecies of Red Deer found in Asia and is endemic to the mountains of Kashmir in the north-western Himalayan region of India. At present, the only viable Hangul population is confined to the 141 sq. km Dachigam National Park (NP), with a few isolated Hangul herds in its adjoining protected areas. Here, we present our recent (2001-2008) assessment of the Hangul's status and conservation in the Kashmir region based on intensive monitoring in Dachigam NP and extensive surveys carried out all over the Hangul's erstwhile stronghold and range. Our range-wise surveys indicate that at present the last surviving and genetically viable Hangul population of 140-170 individuals is restricted to Dachigam NP. A few isolated Hangul populations are also present in the adjoining conservation reserve areas of Bren-Nishat (11 Hangul), including Cheshmashahi Forest Reserve, south-west of Dachigam NP, where a direct sighting of two Hangul females was made in autumn; Khrew (2-6 Hangul); Khanagund (1-2 Hangul); Shikargah (7-12 Hangul) and Overa Wildlife Sanctuary (6 Hangul). Besides, Hangul use the Surfrao and Akhal blocks of Sindh Forest Division, north-east of Dachigam NP, during spring and summer. A group of about 12 Hangul was sighted north of the holy Amarnath cave, which falls just outside the demarcated boundaries of the Overa-Aru and Baltal-Thajwas wildlife sanctuaries, east of Dachigam NP. The current population trends indicate that the species could go extinct if the necessary serious interventions are not made immediately. This study attributes the decline in Hangul population to low breeding, female biased sex ratio, the problem of survival of the young, inadequate recruitment of fawns to adulthood due to factors such as considerable predation by the Leopard *Panthera pardus* and Asiatic Black Bear *Ursus thibetanus*, poaching and continued degradation of Hangul summer habitats in Upper Dachigam, along with biotic interference in winter habitats, and the movements of Hangul in summer to unprotected areas in Sindh Forest Division outside Dachigam NP and the excessive biotic interferences therein. Significant parasitic infestations have also been found in faecal samples of Hangul in Dachigam NP. The Hangul population in Dachigam NP and its adjoining areas thus needs immediate attention. An intensive population monitoring programme, studies of the reproductive ecology and movement patterns of the Hangul and monitoring its health to understand better the factors affecting the population growth and biology and other aspects of Hangul ecology are required for effective management and long term conservation. Population studies indicate a decrease in genetic heterozygosity over time and thus there is a need for urgent measures to arrest the loss in heterozygosity and declining trend of the Hangul population. There is an urgent need for a Hangul recovery plan to be developed that includes field surveys to identify corridors to help dispersion and reintroduction of Hangul to its former distribution range and habitat protection in Upper Dachigam and other potential Hangul habitats outside Dachigam. A captive breeding plan for the Hangul is important to repopulate existing good habitats in the Hangul range, beginning with the Shikargah-Overa ranges in Lidder Valley.

Key words: Hangul, *Cervus elaphus hanglu*, Red Deer, Dachigam, viable population, Zanskar Range, Kashmir

INTRODUCTION

The Hangul or Kashmir Stag *Cervus elaphus hanglu*, listed as a critically endangered deer in the IUCN's Red Data Book (Simon 1966; IUCN 2006), is one of the four easternmost subspecies of Red Deer that are found in Asia (Grzimek 1990; Geist 1998). However, unlike Red Deer and Wapiti *Cervus canadensis*, which have a wider distribution, extending from western Europe to central Asia, and North America and Canada (Ellerman and Morrison-Scott 1951; Flerov 1952; Corbet 1978), the Hangul has had a restricted

global distribution. Being endemic to Kashmir, it was once distributed widely in the mountains of Kashmir (Gee 1965; Schaller 1969) along the Zanskar mountain range in the North-West Himalayan Biogeographic Zone (2A) (Rodgers and Panwar 1988) of India. The shikar map of Kashmir prepared by the then Maharaja of Jammu and Kashmir, Hari Singh, depicts the past distribution of the Hangul in an arc of 64 km width, north and east of the Jhelum and the lower Chenab river. The distributional range extended from Shalurah and Karen in the Kishenganga catchment over to Dorus in Lolab Valley and the Erin catchments in Bandipora in the north to

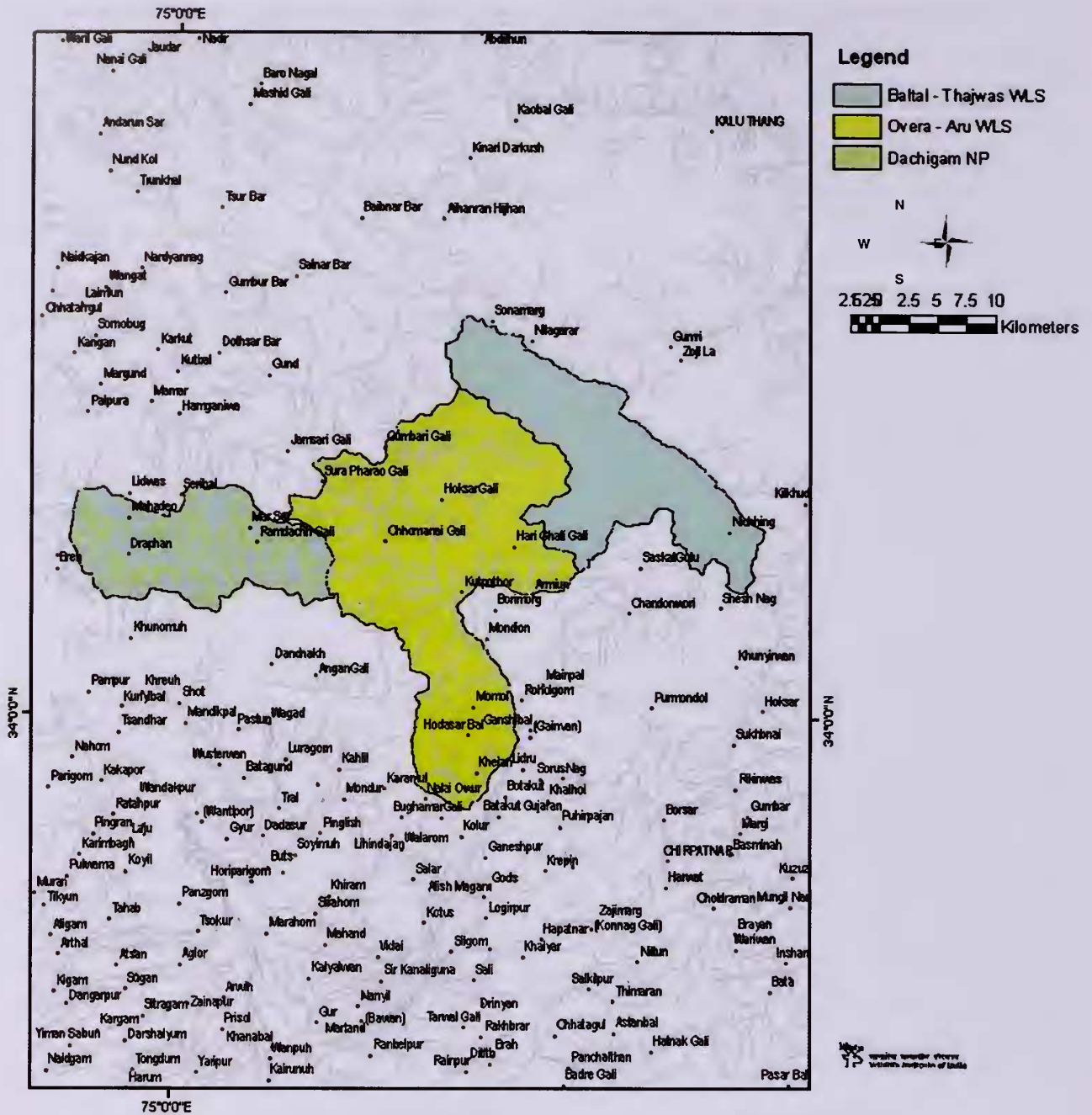


Fig. 1: Dachigam National Park and adjoining Protected Areas

Marwah/Wadwan in Kishtwar High Altitude National Park (NP) in the lower Chenab Valley, and Ramnagar in the south (Lydekker 1924; Holloway and Schaller 1970; Holloway and Wani 1970) (Figs 1, 3) through the present day Baltal-Thajwas Wildlife Sanctuary (WS), Tral Conservation Reserves (Shikargah, Panner & Khiram), Overa-Aru WS, Desu WS and Rajpariyan (Daksum) WS. The Gamgul Siya-Behi Sanctuary in Himachal Pradesh, on the state border, was the only area outside Jammu and Kashmir that probably retained a few Hangul (Holloway 1971).

During the recent past, the Hangul appears to have been wiped out from its past distribution range, possibly due to large scale biotic interference owing to habitat fragmentation and degradation, and poaching. At present a viable population of Hangul occurs only in Dachigam NP, with a few isolated populations in the adjoining areas.

The estimated population of Hangul in Kashmir in 1900 was 3,000-5,000 and in 1947, there were c. 2,000 Hangul still surviving. But 10 years later, the population drastically reduced to about 400 individuals (Gee 1966). The estimates

of the Hangul population between 1969 and 1970 range from not more than 180 individuals (Schaller 1969) to 140-170 (Holloway 1971).

Estimates over the years of the Hangul population in Dachigam and adjoining areas show wide fluctuations, with a drastic decline during the recent past from the 1980s (Fig. 2). The decline in the Hangul population from 2,000 in 1947 (Gee 1965) to 140-170 in 1970 (Holloway 1971) and 175 in 1992 has been attributed to the continued degradation of the Hangul's summer habitat of Upper Dachigam (Holloway 1971; Kurt 1978) and the continued irregular biotic interference in its winter habitat of Lower Dachigam in the past, besides excessive poaching.

Despite the critically endangered status of the Hangul, the species had been very poorly studied compared to its conspecifics the Red Deer of Europe and Wapiti, and other deer species in India. Some information, however, existed on the Hangul, mostly in the form of brief accounts by hunters (Ward 1921; Stockley 1936) stressing shooting exploits and naturalists stressing conservation problems (Talbot 1959; Gee 1965; Schaller 1969; Holloway and Schaller 1970; Holloway and Wani 1970; Caughley 1970; Kurt 1978; Oza 1977; Shah *et al.* 1984; Mishra 1986; Iqbal 1986; Inayatullah 1987). Some accounts deal with general information about the Hangul (Lydekker 1915; Flerov 1952; Whitehead 1972; Lowe and Gardiner 1974; Schaller 1977; Groves and Grubb 1987; Geist 1998) with the exception of the few brief survey reports and natural history accounts mentioned above, carried out prior to the 1990s, and the routine annual Hangul population census carried out by the Wildlife Protection Department of the Jammu & Kashmir Government, no intensive studies had been carried out on the aspects of Hangul ecology prerequisite for its effective long term survival and conservation planning. Here, we present the results of our surveys (2001-2008) and intensive study on Hangul ecology in Dachigam NP and the Hangul's erstwhile distributional range in Kashmir. We also summarize the critical factors that affect the Hangul and its habitat and are prerequisite for the effective management and long term conservation and survival of the Hangul and its habitat.

STUDY AREA

The area of the intensive study, Dachigam NP, holding the last genetically viable population of the Hangul, lies between 34° 05' 00" N to 34° 10' 32" N and 74° 53' 50" E to 75° 09' 16" E. The mountain ranges enclosing Dachigam NP are a part of the great Zaskar Range, which forms the north-west branch of the Central Himalayan Axis, bifurcating near

Kullu (Himachal Pradesh) and terminating in the high twin peaks of Nun Kun (7,135 m). The entire Hangul distributional range is characterised by complex crystalline rocks, granites, gneisses and schists which form the core of the Zaskar Range, a fold of which encloses the Dachigam NP. This complex is partly sedimentary and consists of slates, phyllites and schists with embedded crystalline limestone (Lydekker 1876). Most of the sediments composing these ranges have been laid from the Cambrian to the Tertiary period, and ridged and folded up over the ages (Wadia 1961). The area exhibits a variety of vegetational types characterised by the habitat, form and density of dominant species and controlled by a number of factors including habitat conditions, exposure, altitude and, above all, the degree of biotic interference (Singh and Kachroo 1978). The low lying areas, from 1,700 to 3,000 m, have a complex mixture of vegetation types, with broad leaf mesophyll forests of *Acer caesium*, *Morus alba*, *Ulmus* spp., *Rhus succidiadina*, and *Juglans regia*, *Parrotiopsis jacquemontiana* and a variety of conifers such as Deodar *Cedrus deodara*, Blue Pine *Pinus wallichiana*, Spruce *Picea smithiana* and Fir *Abies pindrow* growing in an altitudinal sequence (Holloway 1971; Singh and Kachroo 1978). The upper reaches, from 3,000 to c. 4,700 m, comprise a vegetation gradient of a subalpine forest community followed by scrub vegetation of Birch *Betula utilis* and Rhododendron *Rhododendron* spp. interspersed with herb-rich grasslands and meadows above 3,300 m. This zone gradually merges into the zone of permanent snow, which is above 3,500 m (Holloway 1971; Singh and Kachroo 1978). The main vegetation types in the area as per Champion and Seth (1968) are typical of Himalayan moist temperate forests: they are of the subalpine forest and alpine forest types.

The climate of the study area may be described as sub-Mediterranean to typically temperate, with higher degrees of variation in precipitation and dryness. Generally, two spells of dryness are experienced, one in June and another in September-November. Snow is the main source of precipitation and in some parts melts till June. Four distinct seasons occur in a year: spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). The monthly mean temperatures recorded during the study period ranged between a maximum of 32 °C in August 2002 (late summer) and a minimum of -5.8 °C during January 2003 (mid-winter) (Ahmad 2006). The soil depth on the slope in the study area from the lower to the middle reaches is less than 25 cm, and hence falls under the category of very shallow soils (Bhat 1985). The annual minimum and maximum rainfall of Dachigam and adjoining areas have been calculated as ranging between 32 mm and 546 mm (Bhat 1985).

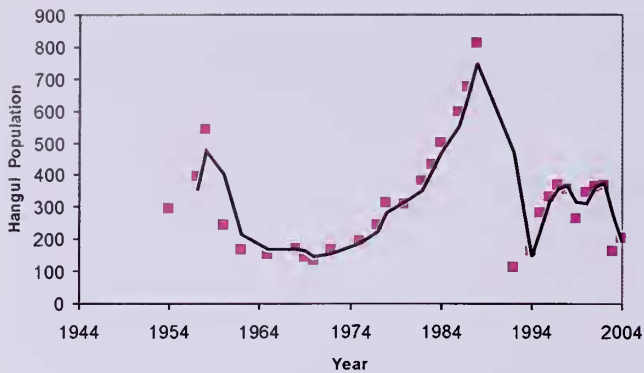


Fig. 2: Population trend in Dachigam and adjoining areas from 1954 to 2004 (Gee 1966; Holloway 1971; Kurt 1969; Department of Wildlife Protection 1970 till 2004; Qureshi and Shah 2004; Ahmad 2006: this study)

METHODOLOGY

This ecological study on the Hangul was aimed at enhancing the scientific knowledge on the aspects of Hangul ecology that are prerequisite for its effective management and long term conservation. We carried out intensive studies on Hangul ecology in Dachigam NP on a regular basis (2001-2004) besides extensive surveys (2004-2008) in the Hangul's erstwhile range areas, including Dachigam NP. Hangul distribution, abundance, habitat use, food and feeding habits were investigated along stratified trails/transects (1 to 2 km length), and survey blocks, on a rotational basis 3-4 times a month in different day hours. For intensive studies in Dachigam NP, the study area was stratified into 7 transects varying in length between 1 and 2 km and in 7 survey blocks (Fig. 4), based on differences in altitude, slope, aspect, floristic composition, degree of human disturbance and administrative beat. Each transect was monitored on a rotational basis three times a month according to the line transect method (Burnham *et al.* 1980), and blocks were intensively surveyed along trails, *nullahs* (streams) and contours according to the trail monitoring method (Rutledge 1982) on a rotational basis four times a month in different seasons and different time periods of the day, for data collection and investigations on Hangul distribution, abundance, habitat use, food and feeding habits. Data based on direct Hangul sightings were collected on these transects and survey blocks. For each sighting, several parameters were recorded, including the time of animal sighting, group size and group composition (males, females, young/yearlings and unknown sex). Besides, data on indirect evidence of Hangul (dung/pellets) wherever found were also collected in 59 (2 × 20 m) belt transects randomly laid in 5 survey blocks for habitat use and dietary investigations. Attempts were also made to investigate the feeding habits of Hangul based on scan sampling following Altman (1952) or following the groups.

Besides the intensive surveys in Dachigam NP, an extensive reconnaissance of the erstwhile stronghold areas of the Hangul's pre-1947 distributional range was carried out to assess the present status and distribution of the Hangul outside Dachigam NP. The survey areas were selected based on unconfirmed reports from the Hangul's past distributional range areas, extending from Keran in the Kishanganga catchment area and Dorus in Lolab Valley of Bandipora to Kishtwar NP. The areas covered in the surveys and interviews with local people and livestock herders include (1) Surfrao and Akhal forest blocks of Sindh Forest Division, and Baltal-Thajwas WS, north and north-east of Dachigam NP; (2) Brein, Nishat and Cheshmashahi Conservation Reserve to the west and south-west of Dachigam NP; (3) Hajan and Satara blocks of Tral Conservation Reserve and Shikargah/Panner Conservation Reserves south-east of Dachigam NP; and (4) Overa-Aru WS in the far eastern part of Dachigam NP (Fig. 1).

In each of these areas, the survey units were selected based on unconfirmed reports of Hangul presence available with the forest and wildlife staff and local people. A forest and wildlife beat was considered as a unit for sampling Hangul presence and habitat assessment (Jhala *et al.* 2005). Furthermore, to ascertain the status of the Hangul in its western range areas, we interviewed local people, livestock herders and army personnel deployed in Gurez and Bandipora about the past and current occurrence of the Hangul.

Hangul habitat suitability and biotic interference assessment was also carried out in Dachigam NP and its adjoining areas to identify the potential units in the Hangul's past distribution range areas outside Dachigam NP for relocation/reintroduction of some Hangul and the possibility of monitoring them continuously.

Hangul relative abundance was estimated following Burnham *et al.* (1980). The chi-square test and ANOVA were performed for analysis of population data. All statistical analyses were performed using the computer program SPSS following Norris (1990). The typical group size was computed following Jarman (1974). Hangul densities were estimated from the Hanguls seen on the transects. Visibility correction was not employed. These densities are merely relevant in terms of relative comparisons. The Hangul population viability analysis (PVA) and the possible risk of extinction of the Hangul in the near future was evaluated using the widely used structured PVA (Caughley 1994; Akcakaya 2000a,b) with the help of the software program Vortex 9.6 (Lacy 2000). This model was run on the basis of population characteristics reported for the Red Deer and Hangul, including data gathered for the Hangul during this study.

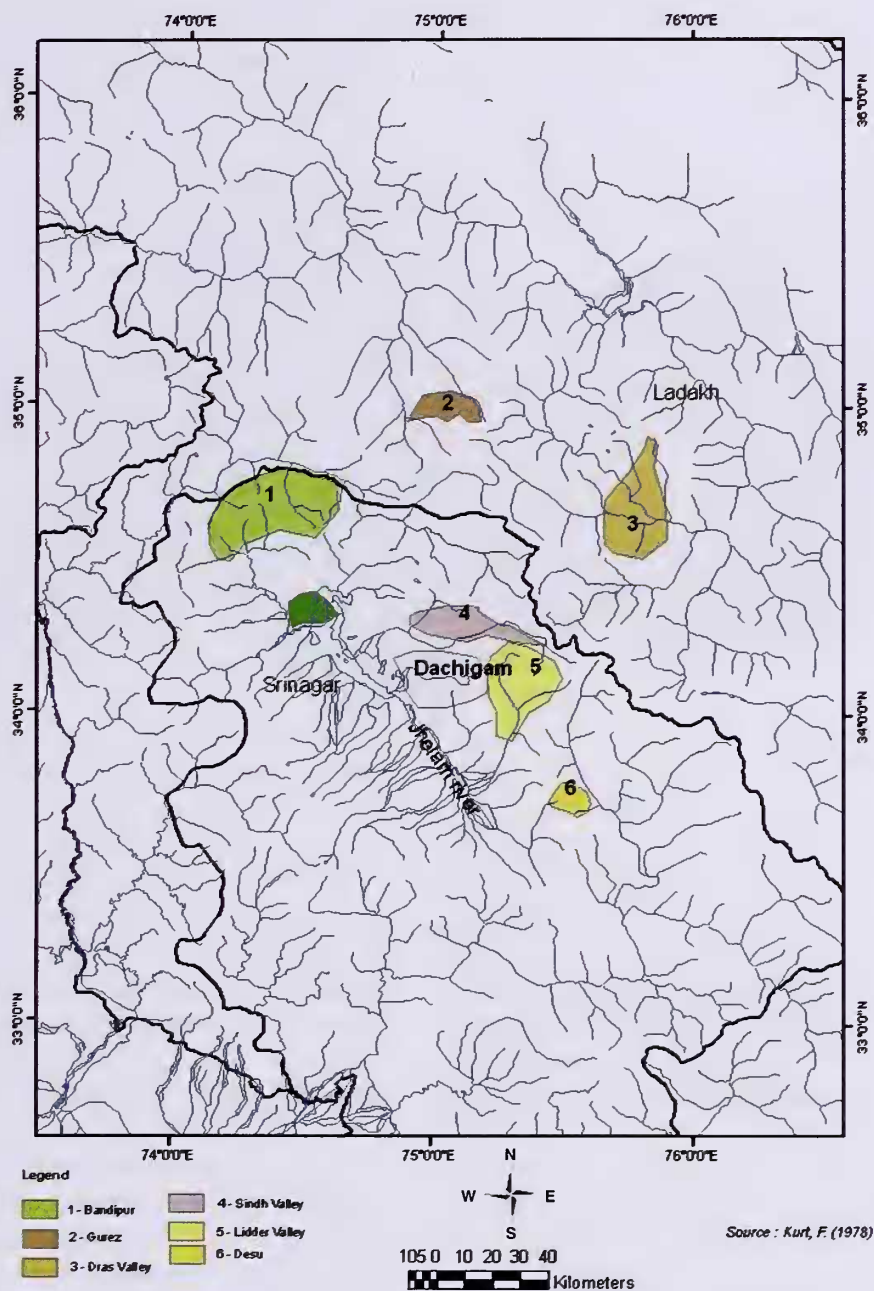


Fig. 3: Past distribution of Hangul in Kashmir Valley

During our intensive studies in Dachigam NP, 693 surveys in the form of trail or transect monitoring were carried out in 7 transects and 5 fixed survey blocks that involved a time and distance effort of 1,839 hours and 5,668 km, respectively, distributed almost equally in the 4 seasons (416 hours and 1,263 km in spring; 473 hours and 1,428 km in summer; 418 hours and 1,276 km in autumn; and 532 hours and 1,701 km in winter).

RESULTS

Our intensive studies and extensive range-wise surveys

in almost all the erstwhile areas of the Hangul in Kashmir clearly indicate that at present the last genetically viable population of the Hangul occurs only in the 141 sq. km Dachigam NP in Kashmir and that a few isolated populations occur in the adjoining conservation reserves of Bren-Nishat (11 Hangul), including Cheshmashahi Forest Reserve, southwest of Dachigam NP, Khrew (4-6 Hangul); Khanagund (1-2 Hangul); and Shikargah (7-12 Hangul) and in Overa WS (c. 6 Hangul). Besides, some stray Hangul groups have been sighted in Sindh Forest Division to the north and north-west of Dachigam NP, including 6 Hangul (1 male, 3 female and 2 young) sighted on the trail between Surfrao and Akhal

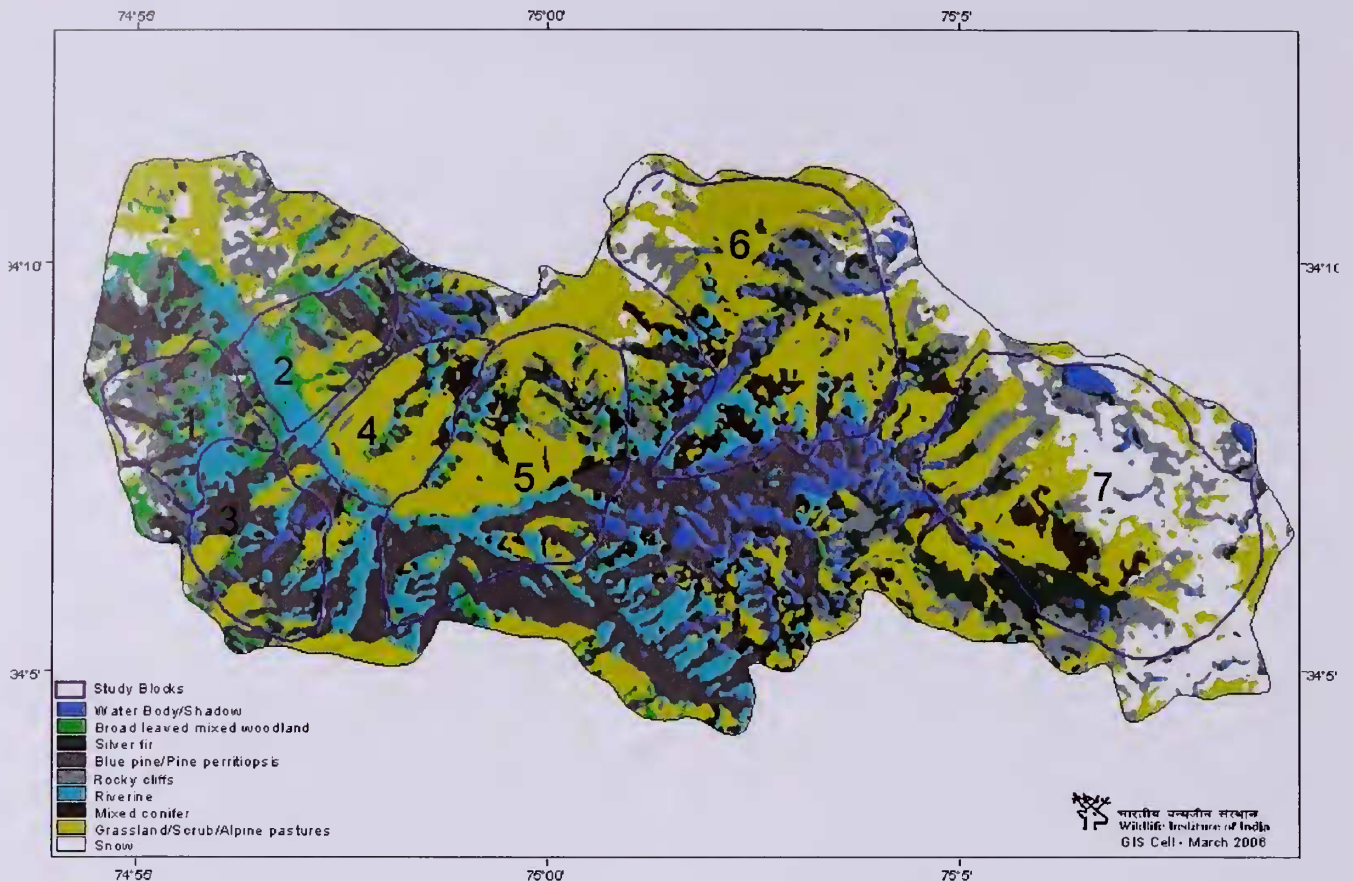


Fig. 4: Location of study blocks in DNP

blocks of the Sindh Forest Division. Of 5 Hangul individuals which fell into the Sindh river near Kangan Forest Block in June 2006, 2 females were rescued and brought to Pahalgam Zoo, in south Kashmir; these were subsequently preyed upon by Leopard *Panthera pardus*.

In 2004, we estimated the Hangul population to be between 146 and 249, with a mean of 197 animals. In 2006, the Hangul population was estimated between 117 and 190 animals, with a mean of 153 animals, whereas in 2008 the population estimates turned out to be between 170 and 190 animals. There appears to be a marginal decline in the Hangul population between 2004 and 2006, which is statistically significant ($t=2.24$, $P=0.06$). The Hangul population showed a decreasing trend in recent years in Dachigam and adjoining areas.

In Dachigam NP, during February 2001 to December 2004, a total of 326 Hangul sightings were recorded, and the maximum Hangul sightings (101) were recorded in winter, followed by 85 Hangul sightings each in spring and autumn. During summer only 55 Hangul sightings were recorded. Hangul encounter rates both per hour effort and per kilometre walk showed a decrease from spring to summer, followed by a gradual increase from summer through autumn to winter.

The maximum Hangul encounter rates (2.02 individuals/hour effort and 0.67 individuals/km walk) were recorded in spring, followed by 1.17 individuals/hour effort and 0.55 individuals/km walk recorded in winter. The minimum encounter rates of 0.41 individuals/hour effort and 0.14 individuals/km walk were recorded in summer. Hangul encounter rates/hour effort or per kilometre walk showed significant differences between different seasons ($F=42.218$, $P=0.001$ and $F=42.44$, $P=0.001$, respectively). The overall Hangul encounter rates/hour effort and per kilometre walk also showed significant differences between the study blocks ($F=173.71$, $P=0.001$ and $F=193.37$, $P=0.001$, respectively). The overall (weight for block area) Hangul density in the intensive study area of Dachigam NP was 5.60 ± 1.13 SE Hangul/sq. km, and it varied between the seasons. The maximum Hangul density (9.02 ± 0.14 SE/sq. km) was recorded in winter, and the minimum Hangul density (0.71 ± 0.05 SE/sq. km) was recorded in summer.

The survey results also indicated wide fluctuations in overall Hangul group size and composition between the seasons. The group size varied from 55 individuals in spring and 40 individuals in winter to 1 individual in the summer. The overall Hangul mean group size varied between seasons, with the largest in spring (95% confidence limit 5.36 ± 1.28

(c. 1) followed by $(4.86 \pm 0.99 \text{ c. 1})$ in winter. The smallest Hangul mean group size of $1.10 \pm 0.33 \text{ c. 1}$ was recorded in summer. The overall typical Hangul group size was 14.11 individuals, and it varied between the seasons from 17.50 individuals in spring to 5.28 individuals in summer. The overall Hangul group composition was 4.30 male, 7.52 female and 5.20 young, and it varied between seasons. As with the Red Deer, the Hangul showed wide sexual segregation. Out of 326 Hangul sightings recorded, Hangul males occurred singly (17% sightings), or in groups of their own, whereas in 18.46% of the sightings, the Hangul groups comprised females only. In 29.54% of the sightings, the Hangul was found in groups of females and fawns. The overall Hangul sex ratio was 23.23 males per 100 females (SE=2.60) and 29.95 young per 100 females (SE=1.90). The overall fawn-to-female ratio was 29.95 ± 1.90 (SE) young/100 females. The Hangul population in Dachigam NP shows a 7.9% increase in growth rate ($r=0.079$ SD; $(r)=0.129$); the population will increase to 291.74 Hangul SE=1.51) and stabilise by the 20th year, given that the carrying capacity of the habitat is 300 and there is a low level of poaching (5%). The sensitivity analysis indicated that there is a 25% chance of extinction in 100 years. The population analysis indicates a decrease in genetic heterozygosity over time.

Outside Dachigam NP, the Surfrao/Akhal blocks of Sindh Forest Division, north and north-east of Dachigam NP, Shikargah and Khiram conservation reserves and Overa-Aru WS, to the east and south-east of Dachigam NP, were observed to support a considerable relic population of the Hangul.

DISCUSSION

The current trend of the Hangul population indicates that the species could go extinct if serious management and conservation interventions are not made immediately. Our studies and survey observations indicate that some of the major issues concerning the decline in the population and long term conservation and survival of the Hangul are the highly skewed female biased sex ratio and very low fawn-to-female ratio, predation by Leopard, poaching to some extent and summer dispersal of the Hangul to unknown unprotected areas in the north-west of Sindh Forest Division, outside Dachigam NP, besides some biotic interference by livestock grazers (Iqbal *et al.* 2004; Qureshi and Shah 2004; Ahmad 2006; Ahmad and Khan 2007).

The study results indicate that the social structure, distribution and movement patterns of the Hangul in Dachigam NP are closely associated with the season, topography and changing vegetation and biotic interference patterns over the seasons. In the later half of winter and early

spring, i.e., between February and May, there is fresh growth of grasses, herbs, sedges and dwarf shrubs, and flowering of trees, resulting in the downward movement of Hangul from higher to lower elevations and congregation in the ravines, as the mountain peaks surrounding the Park remain under snow cover. In contrast, in summer, the Hangul remains dispersed at higher altitudes moving even outside the Park. This is evidenced by the far fewer Hangul sightings and encounter rates during summer. The deciduous forest conditions, together with the fresh forage, probably improved the visibility of and favoured the sighting of comparatively large group sizes in springs and winter compared to summer and autumn, when the shrub and tree canopy cover impaired animal sightings in Dachigam.

The occurrence of the Hangul in Overa-Aru WS presents an excellent opportunity for a comparative study of its population with that of Dachigam NP. Such a study can throw light on the possible interaction between the two populations. Furthermore, Overa-Aru WS, together with Shikargah/Khiram Conservation Reserve, with which it shares a boundary (Fig. 1), similar to Dachigam NP in topography, climate, and vegetation, can prove to be a suitable habitat for a second viable population of the Hangul outside Dachigam NP. In the past as well, the largest population of Hangul outside Dachigam NP was believed to be supported by the Overa-Lidder forests (Inayatullah 1987). However, the latest census, conducted in March 2000 by the Department of Wildlife Protection, indicates that the Hangul population within and around Overa-Aru WS is 37, which include 12 males, 20 females and 5 fawns. This gives the Sanctuary added importance and calls for special efforts towards the conservation and management of its habitats and wildlife therein. Except for the annual census, conducted by the department, there has hardly been any efforts so far to ascertain scientifically the actual size of the Hangul population of Overa-Aru. As such, information regarding the herd composition sex ratio and home range of the Overa Hangul is lacking. Overa-Aru WS and Sindh Forest Division, falling in the distributional range of the Hangul, are closely linked with Dachigam NP through forest corridors which show a strong vegetational contrast with Dachigam NP as they have been subjected to various types of biotic interferences. With the exception of some steep slopes, the natural vegetation has been replaced in these forest corridors in the valley by cultivated plants along roadsides, and stream sides, and in orchards (Kurt 1979a,b).

In Gurez, some isolated Hangul have also been found to occur. This population might possibly be the only resident western population of Hangul in its erstwhile distribution range. However, this needs to be verified. This area could as

well serve as an ideal habitat for the reintroduction of more Hangul.

The livestock grazing and biotic interferences seemed to show some significantly positive impacts on the movement patterns of Hangul in Dachigam NP. Block 5 of Dachigam NP, in which average livestock dung densities of $25.40 \pm 17.67/\text{sq. km}$ of cattle and $132.77 \pm 92.83/\text{sq. km}$ of sheep/goat were recorded during the grazing season (summer-autumn) was used less frequently by Hangul during this period compared with the very frequent sightings in the same block in the non-grazing season (winter-spring). The Hangul encounter rates during summer were lowest in Block 5 ($N=2$). The Hangul encounter rates, however, increased in this block in late autumn ($N=35$) and winter ($N=180$). This block, having its upper reaches above 3,000 m, connected to the subalpine and alpine meadows of Upper Dachigam, experiences heavy livestock grazing and biotic disturbances in summer and a downward migration of grazers during autumn. This possibly forces the Hangul to restrict its movements to away from these two blocks.

Similar patterns have been reported in the displacement and dispersion of Elk and Red Deer away from the areas used by livestock in summer (Dalke *et al.* 1965; Mackie 1970; Lonner 1977; Franklin and Lieb 1979; Skovlin and Vavra 1979; Clutton-Brock *et al.* 1982; Clutton-Brock and Albon 1989). As the densities of livestock increased, the effects on Elk and Red Deer increased. The Sambar has also been found to avoid areas which are used by livestock and pastoral settlements (Sathyakumar 1994; Khan 1995). Long term scientific studies and monitoring of the impacts of grazing and habitat degradation on Hangul should continue in the area through the establishment of 3 to 5 exclosures of dimensions 50×50 m in both Lower and Upper Dachigam.

Both direct and indirect evidence suggest that the Surfrao, Akhal and Kangan blocks of Sindh Forest Division attract large populations of Hangul particularly in summer and the beginning of autumn. This might possibly be because the subalpine and alpine meadows of Dagwan, Nagaberan and Marsar of the upper reaches of Dachigam NP, where Hangul used to range in the past (Schaller 1969; Holloway 1971; Kurt 1978) during this season, have been under heavy pressure from biotic interference in the form of excessive livestock grazing by local people, the Gujjar and Bakerwal, and sheep and goats of the Government Sheep Breeding Farm, resulting in the disappearance and displacement of the Hangul from these areas, with the exception of few strays. Significant efforts (30 surveys; 150 hours spent and 300 km walked each in summer and autumn) were expended to assess these subalpine and alpine meadows of Upper Dachigam only during summer and autumn as they were inaccessible during

winter and spring due to heavy snow cover. But no direct sightings or indirect evidence of Hangul were obtained in these meadows of Dagwan, Nagaberan and Marsar of Upper Dachigam (Dagwan, Nagaberan and Marsar of the upper reaches of Dachigam NP). Secondly, since most of the drainages (*Nullahs*) in Dachigam NP were observed to be dried up throughout the year, probably due to the impact of global warming, since the glacial areas of Upper Dachigam have been observed to be snowless even during the beginning of summer. The non-availability of water in the near vicinity might have forced the Hangul, especially lactating females in summer, to move towards the disturbed habitats in and outside Dachigam. This might as well be acting as one of the factors for fawn mortality to predators or even sheep dogs. This, however, needs to be scientifically assessed: in one incident, out of a group of 5 or 6 Hangul that were observed crossing a river in Kangan Block of Sindh Forest Division, only 3 animals could be rescued, whereas others fell in the river and died. Initiation of a GPS-satellite telemetry study can help track the movement patterns of Hangul outside Dachigam NP, and in demarcating the actual area on either side of Dachigam used by Hangul that could be declared as a sanctuary to serve as a summer home for them.

The very low Hangul sex ratio is of great concern for the long term survival of the Hangul population. The sex ratio of the Hangul population based on our 2006 extensive survey observations in Dachigam NP and adjoining areas was 21 ($SE=2.07$) males per 100 females. In 2004, it was observed to be 19 ($SE=1.33$) males per 100 females, with no significant difference between 2004 and 2006 ($t=-0.96$, $p=0.37$). The fawn-to-female ratio seems to be worrying as it shows a significant decline ($t=3.4$, $p=0.01$), to 9 ($SE = 2.11$) fawns per 100 females in 2006 from 23 ($SE=2.93$) fawns per 100 females in 2004. Our intensive monitoring and observations in Dachigam NP alone, based on all the 326 Hangul sightings made with binoculars, so as to avoid any visibility bias, revealed a female biased overall sex ratio of 23.23 males per 100 females ($SE=2.60$) and 29.95 young per 100 females ($SE=1.90$). This observed Hangul sex ratio is lower than the reported ideal sex ratio of 50 to 66.66 males/100 females for Red Deer (Darling 1937; Whitehead 1972; Bonenfant *et al.* 2004). The Hangul sex ratio has never been at such low levels in the past. The Hangul sex ratio in the past is reported to have ranged from 25 to 30 males per 100 females (Holloway 1971; Stockley 1936; Inayatullah 1987).

The very low sex ratio and fawn-to-female ratio could be attributed to significant predation by Leopard on all sex and age classes of Hangul and of Black Bear principally on young deer. Our studies on predator-prey relationships at

Dachigam NP have revealed that the Leopard *Panthera pardus* and the Asiatic Black Bear *Ursus thibetanus* are the major predators in the area and that the Hangul formed a major proportion (about 25%) of the Leopard diet at Dachigam NP (Iqbal *et al.* 2004; Ahmad 2006). In other words, 60% of the biomass of the Leopard diet is constituted by Hangul. This is, however, a grey area of information, and it needs more research. There is a possibility of Hangul predation by other predators such as the Himalayan Yellow-throated Marten *Martes flavigula* in the area which need to be explored. The information obtained by research on the species, particularly on the breeding biology and movement patterns, is still inadequate, and a regulated monitoring of the Hangul populations on a long term scientific basis, particularly during the fawning season and at the time of rut, will help determine the causes of low reproduction and fawn survival in Dachigam and other range areas of the Hangul.

The supplementary food that is being provided to the Hangul in the form of salt and willow leaves at certain fixed spots alone has resulted in habituating Hangul movements around these particular spots. The provisioning of supplementary food in winter is reported to be useful for both male and female deer, preventing greater winter male mortalities in the Red Deer and Elk (Clutton-Brock and Albon 1989; Smith 2001). The same is recommended to be distributed evenly along the main *nullahs* so as to ensure the availability of food and minerals to the Hangul in its distributional areas in Dachigam with minimal efforts during severe weather conditions in winter and spring. The tall grassland and scrub habitats of Dachigam have been used by Hangul as shelters, sources of foraging substrates and as places in which to escape from predators. Their loss due to frequently observed wildfires may represent a significant change in the suitability of these habitats for Hangul use. The establishment of fire lines using the plantation of fire-proof *hatab* (*Parrotiopsis jacquemontiana*) trees to provide natural fire lines in the forests and grasslands of Dachigam may be tried to control fires in the grassland and scrub habitats of Dachigam NP. Controlled and scientific fire management is a tool that will help conserve these pristine Hangul habitats.

An increase in the Hangul population of Dachigam, modelled on the basis of population characteristics reported and studied (2001-2008) for the Hangul and other closely allied subspecies, particularly Red Deer, with a growth rate of 7.9% ($r=0.079$ SD, $(r)=0.129$) is indicated. The population will increase to 292 Hangul (SE=1.51) and stabilise by the 20th year, given that carrying capacity of habitat is 300 and there is a low level of poaching (5%). The growth rate without carrying capacity i.e. the growth rate of Hangul without specifying any carrying capacity limits for its growth in

Dachigam, would be -8.7% ($r=-0.087$; SD, $(r)=0.137$). The sensitivity analysis indicates a 25% chance of extinction in 100 years. The population will have a decrease in genetic heterozygosity over time. The probability of extinction (PE) for the Hangul population without (normal) and with a density dependent recruitment (den-dep-rec) population ranges between 3% and 4% in a scenario having 5 individuals (2 females and 3 males). Increasing the chance of poaching to 39% (cat-poach and cat-poach - woutdd) with additional winter mortality with a 5% chance of occurrence will substantially increase the extinction risk (cat-poach-winter and cat-poach-winter-woutdd) to 90%. The Hangul population needs an intensive monitoring programme to understand better the factors affecting the population growth.

Since the demographically and genetically viable population of Hangul is presently confined to the 41 sq. km area of the lower reaches of Dachigam NP, it is important to expand the range and habitat of the population to the 141 sq. km extent of Dachigam NP, including the alpine meadows of Upper Dachigam, by taking strict measures to make this area free of livestock grazing so that these ideal summer habitats recover and are used by Hangul in summer as it used to be in the past (Gee 1965; Schaller 1969; Iqbal 1986; Rahul Kaul pers. comm. in 2006). Livestock grazing in Upper Dachigam may prove harmful to Hangul in the long run. Apart from competition for food resources (Smith and Julander 1953), chances of transmission of disease also exist as there has been confirmed evidence of transmission of John's Disease to Hangul in Dachigam in 1978 (Inayatullah 1987). Parasitic investigations of 41 Hangul dung samples from Dachigam NP indicated considerable parasitic infestations of (25%) in the free ranging Hangul population. Recent research studies conducted in the Valley of Flowers NP (Kala *et al.* 1997) and Nanda Devi NP and Kedarnath Wildlife Sanctuary (Sathyakumar 1993, 1994, 2004) have shown that in livestock excluded areas the wildlife habitats have recovered extremely well and that populations of flora and fauna have increased.

A Hangul Species Recovery Plan is required to be initiated urgently. It should include field surveys to identify corridors to help the dispersal of the Hangul to its former distribution range and habitat protection in Upper Dachigam and other potential Hangul habitats outside Dachigam besides a conservation breeding plan for the Hangul to repopulate existing good habitats in the Hangul range. Overa WS and Shikargah Conservation Reserve, almost free from human interference at present, would be ideal locations to initiate Hangul reintroduction. These regions held a good population of Hangul in the past and do hold some stray animals (c. 6 individuals estimated in Overa and 7-12 in Shikargah)

today. Besides, these protected areas have diverse and ideal habitats similar to those of Dachigam and close corridor links with Dachigam NP. With the minimum of 10 Hangul which would be required for restocking in an area such as Overa WS, with an assumed carrying capacity of 100 Hangul, and supplementation of 4 more Hangul (2 males and 2 females, each 2 years old), there is a likelihood that the Hangul population will show a growth rate of 5.3% ($r=0.053$ SD, $(r)=0.14$) and the population will grow to 88 Hangul in the next 100 years in Overa WS.

However, the other areas of the Hangul's past distribution, such as the Erin catchments of Bandipora, Baltal-Thajwas WS, Tral Reserve, Desu *rakh*, Rajparyan (Daksum) WS and Kishtwar High Altitude NP, require special attention and immediate management and conservation efforts on scientific lines. Continued monitoring and surveys are required to be carried out in these areas for collecting baseline information on the habitat conditions and biotic interference in these areas *vis-à-vis* the present status and distribution of the Hangul, if any. These data could then be interpolated to assess the re-establishment of these areas as well as corridors for Hangul and reintroduction.

Continued examination of the perceptions and the opinions of the local people living near Dachigam NP and adjoining reserves and erstwhile stronghold areas of the Hangul are necessary for perpetuating an effective long term strategy and a conservation and management recovery plan for the Hangul and its habitats, including an *ex situ* conservation breeding programme.

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